Aircraft Electric/Hybrid-Electric Power & Propulsion Workshop Perspective of the V/STOL Aircraft Systems Tech Committee

Workshop to be held July 28th, 2016 at the Hilton Salt Lake City Center in Salt Lake City, Utah
## Schedule

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<tr>
<td>0700 – 0800</td>
<td>Check-in and Continental Breakfast</td>
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<tr>
<td>0800 – 0830</td>
<td>Introduction and welcome by AIAA</td>
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<td>0830 – 0930</td>
<td>Speakers from adjacent research</td>
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<td>Large Scale Batteries, by R. Chamberlain (invited) and Extreme Electric Machines by Kiruba Haran</td>
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<td>0930 – 1030</td>
<td>Panel: Visions of the Future</td>
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<td>Featuring John Nairus (AFRL), Cheryl Bowman (NASA) and Dr. Babu Chalamala (Sandia National Lab, invited)</td>
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<td>1030 – 1100</td>
<td>Coffee Break</td>
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<td>1100 – 1205</td>
<td>Panel: Activities from AIAA Committees</td>
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<td>Featuring Ilan Kroo (Aircraft Design TC, invited), Craig Hange (V/STOL Aircraft Systems TC, invited), Andrew Gibson (Green Engineering PC, invited), John Nairus (Energy Optimized Aircraft and Equipment Systems PC)</td>
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<td>1205 – 1305</td>
<td>Lunch</td>
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<td>1300 – 1515</td>
<td>Breakout session introduction and rotation through discussion breakout sessions (technology, systems integration, standards, certification, and role of AIAA)</td>
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<td>1515 – 1545</td>
<td>Coffee Break</td>
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<td>1545 – 1630</td>
<td>Reports from breakout sessions</td>
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<td>1630 – 1700</td>
<td>Wrap- Up and Next Steps</td>
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<td>1700 – 1715</td>
<td>Closing Comments by AIAA</td>
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We are advocates for the use of powered-lift technology to provide enhanced capability to new aircraft concepts to promote improvements to the Air Transportation System

- **Military** – Includes austere basing where access to airfields may be denied. Permits dispersion of assets for protection from attack, deployment of assets closer to the front

- **Civilian** – Increasing throughput by opening up unused or underutilized airports and runways. Access to austere areas in the event of emergency or catastrophe

- **UAV** – Permit take-off and landing at or near areas of operational interest. Permit low-speed / hovering operations in certain scenarios (Power line inspection for example)

- **Rotorcraft and Helicopter** – Access to austere locations, thin haul routes, urban commuting, rescue and medical evacuation

- **Personal Air Vehicle** – True “point-to-point” service
Technical & Operational Issues Endemic to V/STOL

- **Powered – Lift**
  - Using thrust to provide lift when aerodynamics are insufficient due to low-speed (low dynamic pressure)
    - Maintaining lift greater than weight
    - Sufficient control power and authority to maintain flight path

- **Flow Field Effects**
  - In-ground-effect induced forces caused by thrust entrainment
  - Thrust impingement and recirculation – Hot gases and their influence on aircraft and environment

- **Noise and Acoustics**
  - On aircraft, near field, and far field
Technical & Operational Issues Endemic to V/STOL

- **Aircraft balance issues**
  - Keeping the thrust at the center-of-gravity (CG)
  - Ability to provide control moments about the CG

- **Internal plumbing and routing**
  - Moving air to other areas of the airframe to provide thrust where it will maintain balance. Takes up important volume in the aircraft.
  - Vectoring nozzles or vectoring engines. Both introduce complexity, weight, and cost.
  - Lift augmentation – Using favorable interactions of the flow to create additional lift – Upper surface blowing, circulation control, ejector nozzles

- **Mission integration issues** – What other requirements are contrary to V/STOL performance e.g. – Supersonic performance for F-35B
Technical & Operational Issues Endemic to V/STOL

• One engine inoperative (OEI) for 2 or more engines
  ▪ Loss in thrust that is countering drag and providing lift
  ▪ Inability to provide restoring moments
  ▪ The promise of a slower take-off and landing should improve safety, not diminish it

• Mechanical solutions to OEI or critical engine inoperative (CEI) are complex, hard to maintain, and expensive

• A wide operating range of airflow momentum requirements to generate the most efficient thrust beg for the use of true variable bypass ratio
  ▪ US / UK, CALF, JAST, X-32, X-35, F-35 all incorporate variable bypass in one form or another
**Addressing Technical & Operational Issues Endemic to V/STOL**

- **Distributed propulsion is a potential revolutionary answer**
  - More propulsors means smaller impact of OEI (ref 2004 study)
  - Smaller propulsors can be integrated on other locations on the aircraft improving effectiveness, freeing up volume, and reducing induced jet effects
  - On / off “binary” throttle settings may be viable (Engine runs “on-design” only)

- **However….**
  - Mechanical complexity associated with ‘n’ turbo-machinery based units is increased dramatically
  - Propulsion sub-systems also went from 2 to ‘n’. There is very little benefit from being used on smaller thrust engines
  - Economies of scale works against DP in turbomachinery efficiency, weight, and manufacturability (Bypass ratio becomes smaller)
Distributed Propulsion

- RSCA Studies 2004 – 2005, EMAX Concept used 22 engines
Addressing Technical & Operational Issues Endemic to V/STOL

- Distributed Electric / Hybrid Electric Propulsion is a potentially a better answer for V/STOL operations
  - Gas generator performance is potentially decoupled from fan performance
  - The number of potential systems architectures increases, but this permits better mission tailoring
Addressing Technical & Operational Issues Endemic to V/STOL

- Transfer of power accomplished via electricity through (relatively) small wiring, not hot air pipes or mechanical rotating shafts
- Power transfer not confined to certain areas due to volume constraints (e.g. Piping fan air across the fuselage is impractical)
- Hot air energy is created and expended in the turboshaft only. There is very little hot air exiting the aircraft
- Fans are used for all thrust
- Fans can be dissimilar in size and momentum
- Does not need to be turboshaft powered. Could be diesel
- Very high bypass ratio. True variable-bypass ratio capability
- An overspeed capability, and a battery augmentation capability
- Electric is really the only way to go for small UAV
Addressing Technical & Operational Issues Endemic to V/STOL

• Issues and concerns
  ▪ Large amounts of sensors, actuators, and data transfer required
  ▪ Integrated airframe & propulsion is required and is complex
  ▪ Cooling systems for embedded components and electrical inefficiencies distributed in the airframe. Active cooling potentially needed for low-speed or hover.
  ▪ Cryogenic and superconducting may be needed to get better efficiencies
  ▪ Existing generator / motor industry not accustomed to working to aircraft power-to-weight goals
Schematic of Distributed Turbo-Electric STOL Aircraft